Modified Maximum Power Point Tracking for Photovoltaic GridConnected Inverter Based on Voltage-Oriented Control

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Abstract: The output power of PV module varieswith module temperature, solar irradiation and loads.And in order to quickly and accurately track the sun, itis necessary to track the maximum power point (MPP) allthe time.In this paper, the topology and thecontrol scheme of the photovoltaic three-phase grid connectedSVPWM inverter based on voltage-oriented control (VOC)connected distribution system is analyzed. In VOC, a currentcontrol loop is used. The currents are controlled in asynchronous rotating dq-frame using a decoupled feedbackcontrol. The simulations of the system based onMatlab/Simulink environment are presented too.

Keywords: Micro Grid, Renewable Energy Sources,voltage-oriented control, SVPWM ,Nonlinear Load

I. INTRODUCTION

Due to global concern on climate change andsustainable electrical power supply, renewable energy isincreasingly getting popular in the developed countries.Among different sources of renewable energy, PV systemis a promising energysource in the recent years as PVinstallations are increasing due to their environmentfriendly operation. Grid-connected PV system has gainedpopularity due to the feed-in-tariff and the reduction ofbattery cost. However, the intermittent PV generationvaries with the change in atmospheric conditions. Thevoltage-power characteristic of a photovoltaic (PV) arrayis nonlinear and time varying because of the changescaused by the atmospheric conditions. The task of amaximum power point (MPP) tracking (MPPT) in a PVpower system is to continuously tune the system so thatit draws maximum power from the PV array. MaximumPower Point Tracking, frequently referred to as MPPT,is an electronic system that operates the Photovoltaic (PV)modules in a manner that allows the modules to produce allthe power they are capable of. MPPT is not amechanical tracking system that “physically moves” themodules to make them point more directly at the sun. MPPTis a fully electronic system that varies the electricaloperating point of the modules so that the modules are ableto deliver maximum available power. Additional powerharvested from the modules is then made availableasincreased battery charge current.In recent years, the gridconnected PV systems have become more popular becausethey do not need battery backups to ensure MPPT. Thetwo typical configurations of a grid-connected PVsystem are single or two stages. In two stages, the first isused to boost the PV array voltage and track themaximum power; the second allows the conversion ofthis power into high-quality ac voltage.

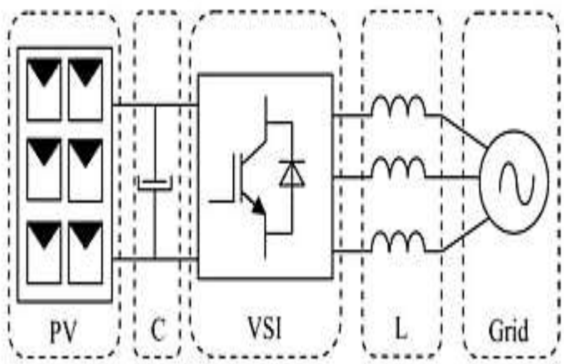


Fig. 1. Typical configuration of a single-stage grid-connected PV system

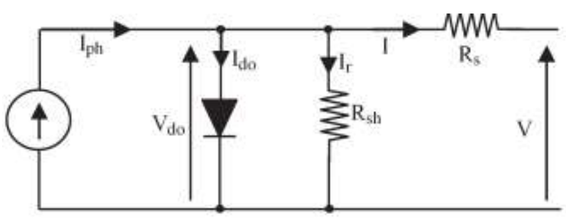
The presence of several power stages undermines theoverall efficiency, reliability, and compactness of thesystem besides increasing the cost. The single stage hasnumerous advantages, such as simple topology, highefficiency, etc. Nevertheless, the control strategy has to bedesigned in order to extract the maximum availablepowerand to properly transfer it from the PV array to thegrid simultaneously. In this case, an importantconsideration in the controller design is needed.In thispaper, the main component of the single-stage gridconnected PV system is the threephase voltage sourceinverter (VSI). Typically, simple inductors L are used asa filter interfacing inverter and mains, as shown in Fig.1. LCL filter provides advantages in costs and dynamicssince smaller inductors can be used. However, in agridconnected system, an LCL filter may causeresonance, which is a disaster for the system's stability[4]. Hence, control systems involving LCL filters areinevitably more complicated. The voltageoriented control(VOC) method used for VSI employs an outer dc linkvoltage control loop and an inner current control loop toachieve fast dynamic response. The performance of thepower flow depends largely on the quality of the appliedcurrent control strategy. In this paper, the current control hasbeen implemented in a rotating synchronous referenceframe d, q because the controller can eliminate asteady-state error and has fast transient response bydecoupling control.A number of techniques are availablein the literature for designing the MPPT. Perturb andobserve (PO), and incremental conductance method arecommonly used techniques in the area of photovoltaicsystems. Among the MPPT techniques, the perturbation andobservation (P&O) method is the most popular because ofthe simplicity of its control structure.

Yet, in the presenceof rapidly changing atmospheric conditions, the P&OMPPT algorithm can be confused due to the fact that it isnot able to distinguish the variations of the output powercaused by the tracker perturbation from those caused by theirradiance variation. Recently, improved P&O MPPTalgorithms for rapidly changing environmental conditionshave been proposed by Sera et al. The signal error of adesigned to reflect the change in power caused by theirradiation variation. Hence, with this information, theproposed algorithm can greatly reduce the power lossescaused by the dynamic tracking errors under rapidweather changing conditions.

II. BACKGROUND WORKS

A. Solar Cell and PV Array Model

A PV generator is a combination of solar cells, connections,protective parts, supports, etc. In the present modeling, thefocus is only on cells. Solar cells consist of a p-n junction;various modelings of solar cells have been proposed in theliterature [14]–[16].Thus, the simplest equivalent circuit of a solar cell is acurrent source in parallel with a diode. The output of the currentsource is directly proportional to the light falling on the cell(photocurrent). During darkness, the solar cell is not an activedevice; it works as a diode, i.e., a p-n junction. It producesneither a current nor a voltage. Thus, the diode determines theI–V characteristics of the cell. For this paper, the electricalequivalent circuit of a solar cell is shown in Fig. 2



.Fig-2 Model of a photovoltaic cell

III. SYSTEM CONFIGURATION

forms.

The circuit model of a typical three-phase voltagesource PWM inverter. S1 to S6 are the six powerswitches that shape the output, which are controlled bythe switching variables a, a1, b, b1, c and c1. When anupper transistor is switched on i.e., when a, b or c is 1,the corresponding lower transistor is switched off i.e.,the corresponding a1, b1c1is 0. Therefore, the on and offstates of the upper transistors S1, S3andS5 can be usedto determine the output voltage.In conventional method of space vector modulation,voltage space vectors are extracted from the grid3phase voltages. Later these vectors are mapped into d–q axis frame And a resultant voltage vector isobtained. Whole space of (2π) has to be divided into 6sectors. For each instantaneous voltage vectorextraction, positions of resultant vector with Respectto the sector have to be determined. Subsequently,switching time calculations for active vectors as well asnull vectors needs to be done. These calculationsdecide the On/off timings for the inverter switchesuch as IGBTS or MOSFETS.As shown in fig.3 eightvoltage space vectors divide the entire vector spaceinto six sectors, namely 1 -6. Except two zero vectors,V0 and V7, all other active space vectors have the same magnitude. there are eight possible combinations of onand off patterns for the three upper power switches.The on and off states of the lower power devices areopposite to the upper one and so are easily determinedonce the states of the upper power transistors aredetermined.

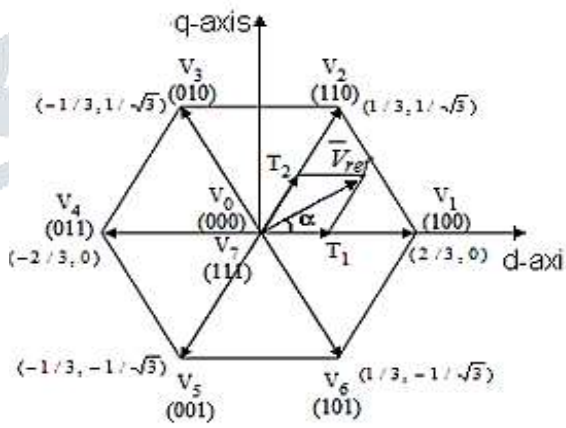


Fig-3 Switching vector and Sectors

SVPWM technique is accomplished by the rotatingreference vector around the state diagram consisting ofsix basic non zero vector forming an Hexagon. Theangle made by d-q quantity is compared with the reference angle which lies between 0° to 360°. Thisconcept is implemented to find the angle of reference voltage vector which frames the different sector of thereference voltage. With this the reference voltage ismade to work in different sectors with different anglewhich covers throughout the entire 360° of operation.

Voltage oriented control: The Voltage Oriented Control (VOC), whichguarantees high dynamics and static performance viaan internal current control loops, has become verypopular and has constantly been developed andimproved. Consequently, the final configuration andperformance of the VOC system largely depends on thequality of the applied current control strategy.Fig.3 shows the system structure of three-phaseSVPWM grid-connected inverter studied in this paper.This system consists of an input filter capacitor C, athree-phase VSI, an output filter. The three-phase VSIwith a filter inductor converts a DC input voltage Udinto an AC sinusoidal voltage by means of appropriateswitch signal to make the output current in phase withthe utility voltage..

To simplify the analysis and design of controller, the space-phase variables of VSI are projected on asynchronously rotating dq-frame. The Fig.4 is thesystem vector diagram based on the grid voltageorientation.

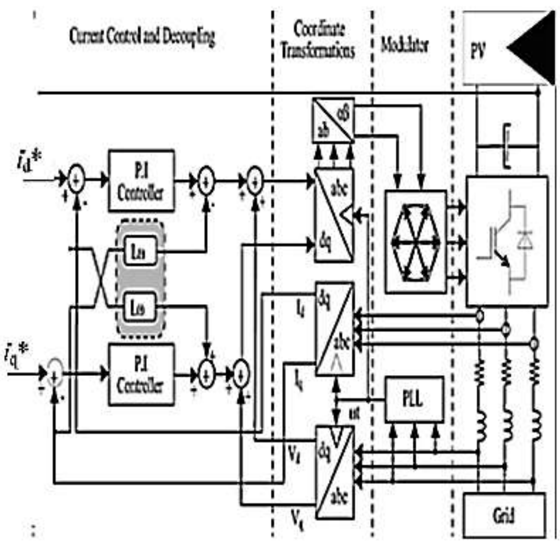


Fig-4: The system block diagram of three-phase SVPWM inverter base on voltage-oriented control

There is cross-coupling between d–axis and q-axiscomponents. However, cross-coupling can affect thedynamic performance of the controller. Therefore, it isvery important to decouple the two axes for betterdynamic performance. The feedward compensationdecoupling control method can be adopted. The controldiagram of decoupling method is shown in Fig. 5

Characteristics of P&O Technique

Although the Perturb and Observe algorithm isthe most widely used for finding the maximum powerpoint, it has a few drawbacks. The P&O technique isslow in finding the MPP and consequently it can fail to produce accurate results in rapidly changingconditions such as rapid changes in weatherconditions, which results in greater oscillation around the ideal operating voltage.

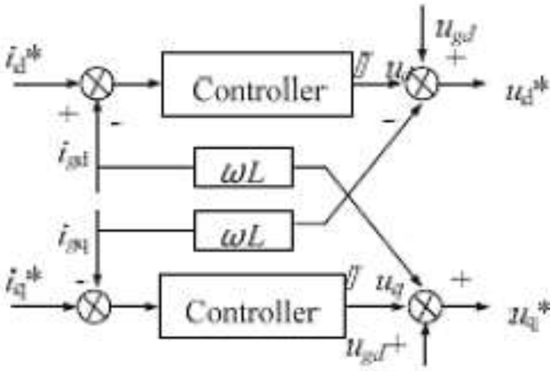


Fig-5: Control block of current decoupling.

The error in themeasurements is further increased by noiseintroduced by the high frequency DC-DC converters.The most basic form of the P&O algorithmoperates as follows. Here it is assumed thatPV module is operating at a point which is away fromthe MPP. In this algorithm the operating voltage ofthe PV module is incremented by a small value andthe resulting change of power, P, is observed. If Pis positive, then it is supposed that it has moved theoperating point closer to the MPP. Thus, furthervoltage increment in the same direction should movethe operating point towards the MPP. If P isnegative, the operating point has moved away fromthe MPP and the direction of increment should bereversed to move back towards the MPP.

IV. SIMULATION RESULTS

This section presents the simulation results of the classicalP&O and the proposed method in order to validate the performance of the control scheme. Computer simulation has beendone using MATLAB/SIMULINK simulation package.

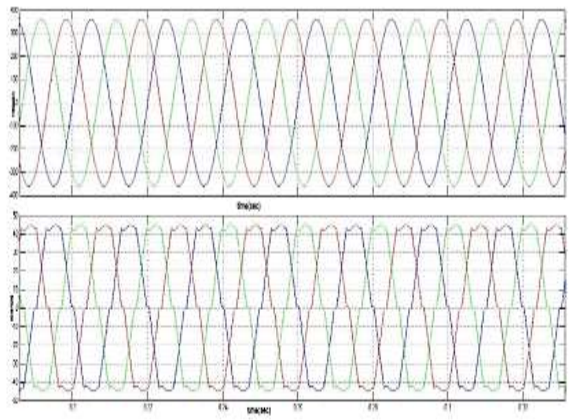


Fig.6 voltage and current wave from at load

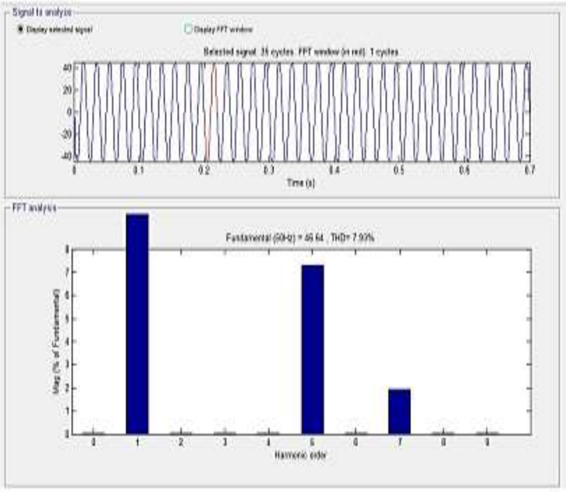
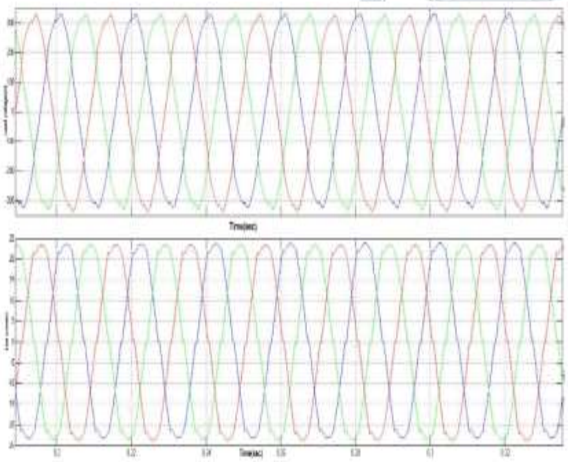


Fig-7 FFT analysis current wave from at load



V. CONCLUSION

The control problem of grid-connected photovoltaic arraysis stated as to provide the maximum of powerirrespective of the solar irradiance conditions. The mainobjective of this paper is, to avoid possible mistakes ofthe classical P&O algorithm due to the fast-changingirradiation.Inthis paper a three-phase grid connected VSI has beenpresented. The comparison distribution system without SVPWM inverter and Voltage-Oriented Controlbase SVPWM inverter when connected to distributionsystem.

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